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Research Article

Length-weight relationships of four difficult-to-sample Caspian endemic gobies (Teleostei: Gobiidae): *Benthophilus persicus*, *Benthophilus baeri*, *Knipowitschia longecaudata*, and *Hyrcanogobius bergi*

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Abstract

The present study provides the length-weight relationships (LWRs) for four difficult-to-sample Caspian endemic gobies for the first time: *Benthophilus persicus*, *Benthophilus baeri*, *Knipowitschia longecaudata*, and *Hyrcanogobius bergi*. They were collected from shallow and deep waters of the southwestern Caspian Sea using various methods, including beach seining, scuba diving, and deepwater bottom beam trawls. The slope (*b*) of LWRs ranged from 2.874 for *B. baeri*, to 3.408 for *H. bergi* with coefficient of determination higher than 0.918. The *b* values showed significant differences between the sexes of all species.

Key words: Baer's tadpole goby, longtail dwarf goby, Persian tadpole goby, Volga dwarf goby

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Introduction

Length-weight relationships (LWRs) of fish are useful in determining their weight and biomass when only length data are available, and are useful in fishery management and conservation (Froese 1998, 2006). Moreover, LWRs have been used in the study of fish conditions and growth patterns (e.g., Ricker 1975).

Gobiids (Teleostei: Gobiidae sensu Gill and Mooi (2012)) of the Caspian Sea (i.e., the world's largest inland body of water, often described as the world's largest lake) include 43 species in 12 genera: 35 species are endemic to the basin, seven species are native to the overall Ponto-Caspian, and one species is exotic (Zarei et al. 2022). LWRs have already been reported for several gobiid species from the Caspian basin (e.g., Abdoli et al. 2009; Mousavi-Sabet et al. 2016). This study provides LWRs for another four species: *Benthophilus persicus* Kovačić, Esmaeili, Zarei, Abbasi & Schliewen, 2021; *B. baeri* Kessler, 1877; *Knipowitschia longecaudata* (Kessler, 1877); and *Hyrcanogobius bergi* Iljin, 1928.

Materials and methods

Using beach seining, scuba diving, and deepwater bottom beam trawls, the fish were collected (1996–2017) from the coastal waters of the southwestern Caspian Sea at Astara (38°25'27.4"N, 48°53'06.2"E), Bandar Anzali (37°30'27.9"N, 49°27'56.8"E), and Chaboksar (36°59'15.0"N, 50°34'01.7"E). Specimens were morphologically identified using Miller (2004) and Kovačić et al. (2021), fixed in 10% formalin, and deposited in the Zoological Museum of Shiraz University, Collection of Biology Department (ZM-CBSU).

Sex determination was achieved through external examination of the urogenital papilla morphology (Miller 2004; Kovačić et al. 2021). Specimens were measured to the nearest 0.1 mm total length (TL) and standard length (SL) using a digital caliper under a Zeiss Stemi sv6 stereomicroscope and weighed to the nearest 0.001 g (total weight, W). The parameters of the length-weight relationships $W = aL^b$ were expressed by linear regression of the log-transformed weight and length, where W is the total weight (g), L is the total length (cm), *a* is a constant being the initial growth index, and *b* is the slope of the log-transformed linear regression. Prior to regression analysis, log-log plots of length and weight values were performed for visual inspection of outliers (Froese 2006). Additionally, 95% Confidence Intervals (CI) for *a* and *b* were estimated. The significance of the regression was tested by ANOVA. To examine the variation of the *b* values between sexes, a Student's *t*-test was used to compare regression coefficients for male and female of the four species (Zar 1974). To test whether *b* values significantly deviated from the expected cube value of 3, Bailey's *t*-test was applied. Covariance analysis was applied to test for a significant difference in the *b* value between the sexes of the four species (Zar 1974).

Results

A total of 410 specimens, including 199 *Benthophilus persicus*, 40 *Benthophilus baeri*, 135 *Knipowitschia longecaudata* and 36 *Hyrcanogobius bergi* were collected (Table 1). ANOVA showed a highly significant difference between sexes in three variables (TL, SL, and W) in *B. persicus* ($p<0.001$) (Table 2). Estimates for length-weight parameters are given in Table 1. The slope (*b*) of LWRs ranged from 2.874 for *B. baeri* to 3.408 for *H. bergi* with r^2 values higher than 0.918. Covariance analysis using Student's *t*-test revealed significant differences between *b* values of males and females in all four species. Furthermore, Bailey's *t*-test in both sexes of the four species showed that *b* values significantly deviated from the expected cube value of 3.

Discussion

The currently limited knowledge on Caspian endemic gobies is mainly due to sampling artifacts, since many species are known only from a few expeditions, and many, including those included in this study, appear to be ecologically restricted to difficult-to-sample deep-water habitats. In all four species, the allometric coefficient (*b*) of LWR is within the expected range of 2.5–3.5 (Froese 2006).

Studies have shown that factors such as season, habitat, sex, gonad maturity, diet, stomach fullness, health, and preservation methods may affect LWRs

Table 1. Descriptive statistics and parameters of LWRs for four species from the Caspian Sea (N – number of specimens; M – male; F – female; TL – total length; W – total weight; *a* – regression intercept; *b* – regression slope; r^2 – coefficient of determination).

Species	Sex	N	TL range (mm)	W range (g)	*a*	95% CI of *a*	*b*	95% CI of *b*	r^2
Benthophilus persicus	M	99	25.0–56.9	0.169–2.080	0.0081	0.0068–0.0099	3.144	3.014–3.274	0.960
	F	100	23.7–55.8	0.162–1.827	0.0097	0.0084–0.0113	3.011	2.896–3.126	0.965
	Both	199	23.7–56.9	0.162–2.080	0.0089	0.0080–0.0100	3.075	2.993–3.157	0.965
Benthophilus baeri	M	20	34.5–65.0	0.735–4.750	0.0184	0.0097–0.0350	2.840	2.452–3.229	0.929
	F	20	41.0–60.9	1.020–3.745	0.0138	0.0078–0.0242	3.039	2.695–-3.382	0.950
	Both	40	34.5–65.0	0.735–4.750	0.0177	0.0116–0.0271	2.874	2.617–3.130	0.931
Knipowitschia longecaudata	M	72	20.4–39.6	0.057–0.356	0.0035	0.0027–0.0046	3.311	3.088–3.534	0.926
	F	63	26.4–40.2	0.089–0.344	0.0027	0.0020–0.0036	3.471	3.222–3.719	0.927
	Both	135	20.4–40.2	0.057–0.356	0.0032	0.0026–0.0039	3.361	3.189–3.533	0.918
Hyrcanogobius bergi	M	25	28.9–38.7	0.161–0.375	0.0032	0.0019–0.0054	3.630	3.178–4.083	0.923
	F	11	28.0–34.9	0.146–0.300	0.0064	0.0039–0.0106	3.050	2.604–3.496	0.964
	Both	36	28.0–38.7	0.146–0.375	0.0042	0.0028–0.0062	3.408	3.061–3.755	0.921

Table 2. Results of ANOVA testing for differences among sexes in four species (W – total weight; TL – total length; SL – standard length).

Species	Variable	Sum of squares	Mean square	F-value	p-value
Benthophilus persicus	W (g)	3.599	3.59	16.119	0.0001
	TL (mm)	1292.00	1292.00	18.519	0.0001
	SL (mm)	739.25	739.25	16.491	0.0001
Benthophilus baeri	W (g)	0.426	0.426	0.433	0.515
	TL (mm)	7.45	7.456	0.116	0.735
	SL (mm)	5.27	5.271	0.119	0.732
Knipowitschia longecaudata	W (g)	0.003	0.003	0.735	0.393
	TL (mm)	1.68	1.68	0.146	0.703
	SL (mm)	6.60	6.60	0.824	0.366
Hyrcanogobius bergi	W (g)	0.426	0.426	0.433	0.515
	TL (mm)	7.45	7.45	0.116	0.735
	SL (mm)	5.27	5.27	0.119	0.732

(e.g., Bagenal and Tesch 1978; Tesch 1971). In *Benthophilus baeri* and *Knipowitschia longecaudata*, the *b* values were larger in females, indicating that females are heavier than males of the same length, which might be explained by differences in gonadal development or nutritional status.

The LWRs provided here should be taken with caution and considered as preliminary since we cannot exclude shrinkage over time (i.e., over years in preservation fluid), and therefore, some of the estimates may deviate from those of freshly collected specimens. Additional data based on fresh specimens and measurements after fixation in formalin for 12–96 hours, as well as 10–50 days, would reveal the shrinking rate over time and enable calculating a correction factor.

The conservation status of Caspian gobiids and species of the South Caspian sub-basin, in particular, has been partially assessed (i.e., 64.9% as Least Concern and 35.1% as Data Deficient and Not Evaluated in the IUCN Red List) (Zarei et al. 2022). The IUCN Red List does not have information about *B. persicus*, and the other three species are under the Least Concern category; however, there is little data and the population trend is unknown. Increased sampling and more reliable metadata on their species distributions, combined with biological and ecological data are needed to determine their conservation status.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

FZ conceived the study, conducted the laboratory work and the data analysis, and wrote the first draft. HRE provided resources for the laboratory work. KA collected the specimens. RS participated in the data analysis.

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Data availability

All of the data that support the findings of this study are available in the main text.

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